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ORIGINAL ARTICLE

Gas-containing brain abscess: Etiology, clinical characteristics, and outcome

Tsung-Ming Su [a,*], Chu-Mei Lan [b], Tsung-Han Lee [a], Shih-Wei Hsu [c]

[a] *Department of Neurosurgery, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan*
[b] *Department of Health Psychology, Chang Jung Christian University, Tainan, Taiwan*
[c] *Department of Radiology, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan*

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Abstract Gas-containing brain abscess remains a life-threatening disease that requires immediate diagnostic and therapeutic intervention. The aim of this study is to report on a series of gas-containing brain abscess and discuss its pathological mechanism and therapeutic consideration. This study included 11 patients with gas-containing brain abscess at Kaohsiung Chang Gung Memorial Hospital, Kaohsiung, Taiwan during a 27-year period. The predisposing factors to infection included hematogenous spread in five patients, contiguous infection in one patient, and abnormal fistulous communication due to head injury in four patients. In one patient, the predisposing factor might be contiguous infection from frontal sinusitis or abnormal fistulous communication due to previous sinus surgery. *Klebsiella pneumoniae* was the most common causative pathogen that was isolated from the gas-containing abscess not related to skull base defect. Among these 11 patients, six underwent excision and five accepted aspiration for the surgical treatment of abscess. In the five patients who underwent aspiration, two required repeated craniotomy to excise the recurrent abscess and repair the abnormal fistulous communication through the skull base. When encountered with a gas-containing abscess in patients with an impaired host defense mechanism, *K. pneumoniae* infection should be suspected, and further attention should be paid to discovering if other metastatic septic abscesses exist. For patients with a history of basilar skull fracture or surgery involving the skull base, craniotomy is indicated to excise the abscess and repair the potential fistulous communication through the cranium. Aspiration may be a reasonable alternative to treat deep-seated lesions, lesions in an eloquent area, patients with severe concomitant medical disease, or patients without a history of basilar skull fracture or surgery involving the skull

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* Corresponding author. Department of Neurosurgery, Kaohsiung Chang Gung Memorial Hospital, 123 Dapi Road, Niaosong District, Kaohsiung City, 83301, Taiwan.
E-mail address: tsungming4516@gmail.com (T.-M. Su).

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base. Prompt diagnosis, appropriate antibiotic use, and meticulous surgical treatment are the only way to obtain a favorable outcome.

Introduction

Even with enormous advances in diagnostic imaging techniques, neurosurgical techniques, and antibiotic therapy, brain abscess remains a life-threatening disease that requires immediate diagnostic and therapeutic intervention. Gas-containing brain abscess is very rare and has been reported to result from bacterial fermentation or escape of air into the cranium through an abnormal communication between the exterior and the cranium [1]. The reported causative pathogens of gas-containing brain abscess include *Clostridium perfringens*, *Klebsiella pneumoniae*, *Peptostreptococcus* species, and *Fusobacterium nucleatum* [2—6]. The management of gas-containing brain abscess is still controversial. The presence of gas within the abscess has been considered an indication for surgical excision [1]. However, aspiration of abscess content only also results in good outcome [2,6]. Herein, we report on a series of gas-containing brain abscess and discuss its pathologic mechanism and therapeutic consideration. Our research is done in an effort to improve the therapeutic strategy of this potentially fatal disease.

Materials and methods

During a 27-year period (1986—2012), 246 patients at Kaohsiung Chang Gung Memorial Hospital, Kaohsiung, Taiwan were retrospectively identified to have pyogenic brain abscess. Inclusion criteria for pyogenic brain abscess were as follows: (1) classical clinical manifestations, including fever, headache, focal neurological signs, and/or altered consciousness; (2) characteristic findings on computed tomographic (CT) and/or magnetic resonance imaging (MRI) scans; and (3) evidence of brain abscess observed during surgery or histopathological examination. Specimens obtained from patients were cultured for aerobic and anaerobic bacteria, mycobacteria, and fungi. In patients with negative cultures, brain abscess was diagnosed according to the classic clinical and radiographic findings and good therapeutic response to combined surgical and antibiotic treatment. Among these 246 patients, gas was noted within the abscess cavity on CT scan in 14 patients (Fig. 1). However, three patients with gas-containing abscess who sustained craniotomy within 1 month before the diagnosis of brain abscess were excluded in this study because it was difficult to clarify the origin of air.

For these 11 patients with gas-containing abscess, the presenting symptoms, underlying disease, predisposing factors of infection, site of abscess, therapeutic methods, outcome, and complication during follow-up were retrospectively reviewed. Predisposing factors for brain abscess include contiguous infection from a parameningeal focus, hematogenous spread from a distant infection site, and abnormal fistulous communication due to previous surgery or head trauma. Neuroradiographic studies were reviewed carefully, and the number, size, and location of abscesses were recorded. Therapeutic choice was judged according to clinical status, neuroradiographic findings, and therapeutic response. The duration of antibiotic treatment depended on therapeutic response. Surgical treatment consisted of either aspiration or excision. Aspiration was defined as aspiration of the abscess content with a ventricular catheter through a burr hole or small craniotomy, leaving the capsule intact. Craniotomy and resection of the abscess was defined as excision. Functional outcome was evaluated 3 months after patient discharge by the Glasgow Outcome Scale (GOS) score as follows: 1 = death, 2 = persistent vegetative state, 3 = severe disability, 4 = moderate disability, and 5 = good recovery [7]. Any adverse event related to the brain abscess during the follow-up period was considered as a follow-up complication.

Results

After excluding three patients who developed gas-containing abscess following recent craniotomy, 11 patients with gas-containing brain abscess were included in this study. Our study found two categories of gas-containing

Figure 1. An enhanced computed tomographic scan showed a faintly ring-enhanced lesion with air—fluid level in the left frontal lobe.

brain abscess. One category was *K. pneumoniae* infection in patients not related to skull base defect. Another was infection secondary to escape of air into the cranium through an abnormal communication between the exterior and the cranium. The clinical features, therapeutic methods, and outcome of these 11 patients are summarized in Table 1.

There were seven males and four females. Gas-containing abscess caused by *K. pneumoniae* occurred most in older adults. By contrast, patients with a history of basilar skull fracture or surgery involving the skull base were younger. Six patients were admitted in a disturbed state of consciousness. Fever was noted in eight patients. Other presentations include headache, vomiting, and hemiparesis. Patient 9 was admitted with diffuse septicemia and in shock status. Diabetes mellitus was the most common underlying disease. Other underlying diseases include head injury, chronic otitis media, liver cirrhosis, and sinus surgery. The predisposing factors to the abscess include hematogenous spread from a remote infection focus in five patients, contiguous infection in one patient, and abnormal fistulous communication due to head injury in four patients. In Patient 1, the predisposing factor might be contiguous infection from frontal sinusitis or abnormal fistulous communication due to previous sinus surgery.

K. pneumoniae was the most common causative pathogen. All were isolated from the gas-containing abscess not related to skull base defect. Other causative pathogens include *Pseudomonas aeruginosa*, *Streptococcus viridans*, and *Peptostreptococcus* species. The culture revealed no growth in one patient. The most common site for gas-containing abscess in these 11 patients was the frontal lobe. Air—fluid level within the abscess cavity was noted in one patient. Basilar skull fracture due to previous head injury was noted in four patients.

Among these 11 patients, six underwent excision and five accepted aspiration for the surgical treatment of abscess. In the five patients who underwent aspiration, two (Patient 2 and Patient 5) required repeated craniotomy to excise the recurrent abscess and repair the abnormal fistulous communication through the skull base. During the procedure of abscess excision, searching for the abnormal fistulous communication through the skull base was performed in four patients. However, abnormal communication was found and repaired in only three patients. Most patients accepted intravenously administered antibiotics for 4—6 weeks based on the therapeutic response. Ten patients survived with favorable outcome after combined treatment. Patient 9 who presented with altered consciousness and septic shock died even with aggressive treatment. After the event of gas-containing abscess, two patients developed complications (recurrent pneumocephalus in 1, recurrent meningitis in 1) during the follow-up period.

Illustrative case report

An 18-year-old man suffered a blunt facial trauma during a motor vehicle accident. On arrival at the emergency room, his blood pressure was 132/70 mmHg and pulse rate was 82 beats/min. On examination, he had facial swelling and ecchymosis over the right cheek. His Glasgow Coma Scale (GCS) score was E4V3M6. His pupils were equal and reactive to light. A facial bone CT scan demonstrated mandibular fracture, basilar skull fracture, and pneumocephalus (Fig. 2A). A brain CT scan revealed pneumocephalus over the right frontal region (Fig. 2B). Two days later, a follow-up brain CT scan demonstrated mild regression of pneumocephalus (Fig. 2C). Surgery for fixation of mandibular fracture was performed 4 days later. He was discharged with an uneventful course. Two months later, he was brought to the emergency room due to altered consciousness for 3 days. On arrival, his GCS score was E2V1M6. According to the statement of his family, he had complained of headaches for 5 days. A brain CT scan demonstrated a ring-enhanced lesion over the right frontal lobe with perifocal edema and marked mass effect (Fig. 3A). Gas within the lesion was also noted (Fig. 3A). Brain abscess was suspected, and he underwent craniotomy to excise the lesion. During the procedure of craniotomy, an abscess with purulent material was excised. After careful exploration, a small hole in the posterior wall of the frontal sinus near the floor of the frontal base was noted and repaired with a dural graft. Culture of the purulent material grew *S. viridans* and *Peptostreptococcus* species. The patient recovered uneventfully after surgery. One month later, an enhanced MRI scan revealed total eradication of the abscess (Fig. 3B). He was discharged without neurological deficits after antibiotic treatment and has remained well for 3 years.

Discussion

Our study may support the previous opinion that gas-containing brain abscess may result from glucose fermentation by gas-forming organisms or escape of air into the cranium through an abnormal communication between the exterior and the cranium [1,5]. In six patients of our study, gas-containing abscess was caused by *K. pneumoniae*, and it has been thought it can ferment glucose to produce acid and gas under anaerobic conditions and form gas-containing abscess, as in previous reports [8,9]. In the other five patients, entrance of air into the cranium through an abnormal fistulous communication caused by previous surgery or head trauma was suspected, although the existence of the fistula can only be found in three cases during surgery.

K. pneumoniae was once thought to be a rare cause of brain abscess in adults [10]. However, it has become an increasingly important cause of brain abscess, particularly in patients with an impaired host defense mechanism, head trauma, or neurosurgical operations [2,11]. In Taiwan, *K. pneumoniae* has been known to cause severe infection, including liver abscess, pneumonia, endophthalmitis, meningitis, and brain abscess, especially in patients with a history of malignancy, liver cirrhosis, alcoholism, or diabetes mellitus [2,8,9,12—15]. Liliang et al [2] suggested when brain abscess occurred in diabetic patients or has a gas-containing appearance, *K. pneumoniae* infection should be suspected and further attention should be paid to discovering if other metastatic septic abscesses exist. Among six patients with *K. pneumoniae* abscess in our

Table 1 Clinical features of patients with gas-containing brain abscess.

Case	Age/sex	Clinical presentation	Underlying disease	Predisposing factor	Causative pathogen	Radiographic findings	Surgery	GOS outcome
1	39/M	Headache, vomiting	Frontal sinusitis	Frontal sinusitis s/p sinus surgery	*Pseudomonas aeruginosa* (pus)	Right frontal, 3 cm	Excision	5
2	27/M	Fever, altered consciousness	Head injury	Skull base fracture	*Staphylococcus aureus* (pus)	Right frontal, 3 cm	Aspiration, excision[a]	4
3	18/M	Headache, altered consciousness	Head injury	Skull base fracture	*Streptococcus viridans* (pus), *Peptostreptococcus* species (pus)	Right frontal, 3 cm	Excision	5
4	20/M	Fever, headache, altered consciousness	Head injury	Skull base fracture	No growth	Right temporal, 3 cm	Excision	5
5	28/F	Fever, headache	Head injury	Skull base fracture	*S. viridans* (pus)	Left frontal, 3 cm	Aspiration, excision[a]	5
6	62/M	Fever, headache	Diabetes mellitus	Hematogenous spread (urinary tract infection)	*Klebsiella pneumoniae* (pus)	Right temporal, 3 cm	Excision	5
7	42/F	Fever, headache, altered consciousness	Liver cirrhosis	Hematogenous spread (pneumonia)	*K. pneumoniae* (pus)	Right parietal, 3 cm	Aspiration	4
8	68/F	Headache, hemiparesis	Diabetes mellitus	Hematogenous spread (urinary tract infection)	*K. pneumoniae* (pus)	Left frontal 2.5 cm	Excision	5
9	51/F	Fever, altered consciousness, shock	Diabetes mellitus	Hematogenous spread (pneumonia)	*K. pneumoniae* (pus)	Left frontal, air—fluid level, 5 cm	Aspiration	1
10	51/M	Fever, headache	Diabetes mellitus, chronic otitis media	Otogenic infection	*K. pneumoniae* (CSF)	Left temporal, 3 cm	Aspiration	5
11	66/M	Fever, altered consciousness, hemiparesis	Diabetes mellitus, liver cirrhosis	Hematogenous spread (urinary tract infection)	*K. pneumoniae* (pus)	Left parietal, multiloculated, 6 cm	Excision	5

CSF = cerebrospinal fluid; F = female; GOS = Glasgow Outcome Scale, 1 = death, 2 = persistent vegetative state, 3 = severe disability, 4 = moderate disability, 5 = good recovery; M = male.

[a] Excision to eradicate the recurrent abscess.

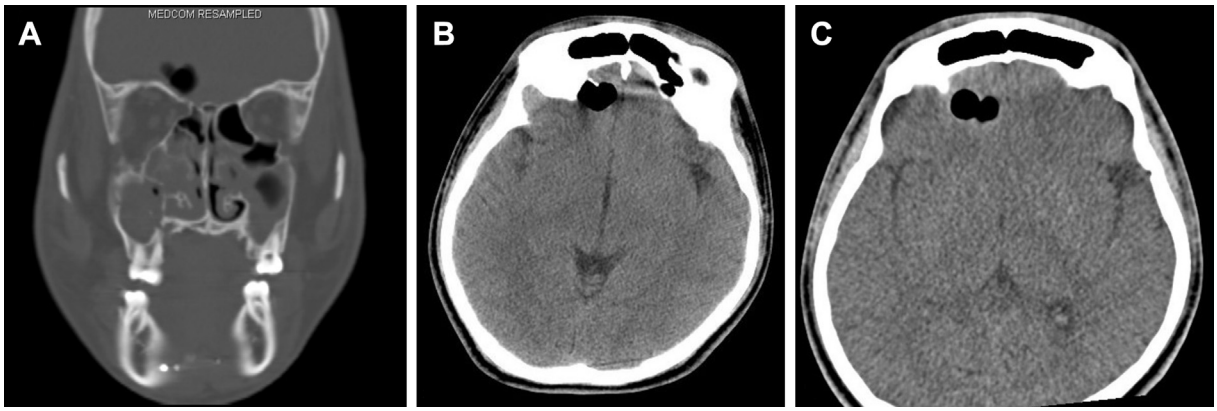

Figure 2. (A) A coronal facial bone computed tomographic (CT) scan revealed pneumocephalus. (B) A brain CT scan demonstrated pneumocephalus over the right frontal region. (C) Follow-up brain CT scan found mild regression of pneumocephalus.

study, diabetes mellitus was noted in five, and two had a history of liver cirrhosis. Five of them had other metastatic infectious foci.

Gas-containing brain abscess can occur by direct inoculation of *C. perfringens* from surgery or penetrating head trauma [6,16]. In our study, three patients who developed gas-containing abscess after recent craniotomy were excluded because it was difficult to clarify the origin of gas. Escape of air into the cranium through an abnormal fistulous communication is another possible mechanism to form gas-containing abscess following surgery or head trauma [1], as in our study. Pneumocephalus is common in patients with basilar skull fracture or following surgery. But to our knowledge, the incidence and causative pathogens of gas-containing abscess due to air entrance into the cranium following head trauma or surgery have never been studied.

In our study, gas-containing brain abscess caused by *K. pneumoniae* occurred most in older adults. This can be explained by the fact that some previous studies in Taiwan found that *K. pneumoniae* infections tended to occur in older adults [8,13,15]. The finding that the patients with a history of basilar skull fracture or surgery involving the skull base were younger may be due to the fact that craniofacial trauma occurs more often in young adults in Taiwan [17,18]. The most common location of abscess in patients with a history of basilar skull fracture or surgery involving the skull base is the frontal lobe. A reasonable explanation is contiguous infection from an abnormal communication between the exterior and the cranium due to previous neurosurgical insult.

The management of gas-containing brain abscess remains a controversial issue. The presence of gas within the abscess cavity has been considered an indication for surgical excision [1]. In the case of gas-containing abscess following recent penetrating head injury, it is crucial to remove all bits of foreign material, bone chips, and necrotic tissue [6]. For patients with a history of basilar skull fracture or surgery involving the skull base, craniotomy to excise the abscess and search for the potential fistulous communication through the cranium to prevent recurrent infection is a reasonable consideration [1]. In our study, recurrent abscess was noted in two patients with previous skull base fracture who underwent aspiration to treat the abscess. Craniotomy was performed to excise the

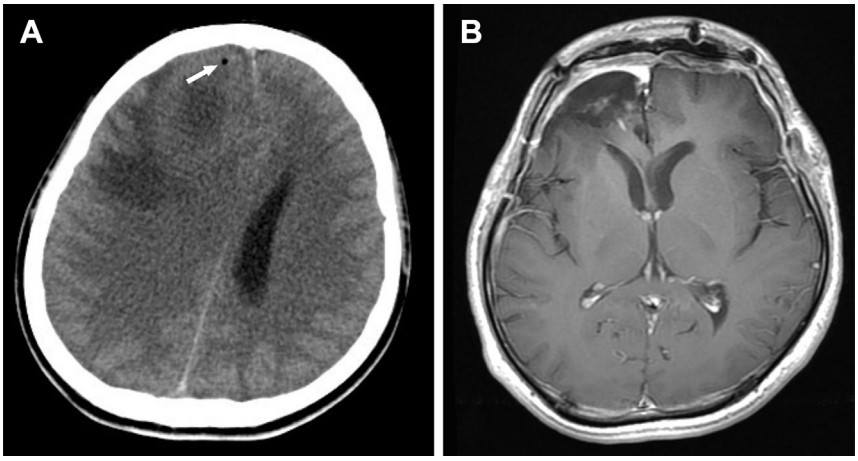

Figure 3. (A) A brain computed tomographic (CT) scan demonstrated a heterogeneous lesion over the right frontal lobe with perifocal edema and marked mass effect. Gas within the lesion was also noted (arrow). (B) Axial T1-weighted magnetic resonance imaging scan with gadolinium enhancement demonstrated total eradication of the abscess.

recurrent abscess and repair the abnormal fistulous communication through the skull base. However, aspiration for gas-containing abscess caused by *K. pneumoniae* also resulted in a favorable outcome [2]. Tekkok et al [6] thought if clostridial abscess flora is monomicrobial, antibiotic treatment combined with aspiration may suffice. So the choice of surgical method for gas-containing brain abscess may depend on predisposing factors, suspected pathogen, radiographic findings, and clinical status. For patients with a history of basilar skull fracture or surgery involving the skull base, craniotomy is indicated to excise the abscess and repair the potential fistulous communication through the cranium. Aspiration may be a reasonable alternative to treat deep-seated lesions, lesions in an eloquent area, patients with severe medical concomitant disease, or patients without a history of basilar skull fracture or surgery involving the skull base. Close surveillance is crucial to detect the recurrence of abscess, and excision is recommended to eradicate the recurrent abscess.

Gas-containing brain abscess can cause rapid clinical deterioration and even death [16,19,20]. Prompt diagnosis, appropriate antibiotic use, and meticulous surgical treatment are the only way to obtain a favorable outcome. In our study, 10 patients survived with favorable outcomes after combined treatment. The only one fatal case presented with altered consciousness and septic shock initially, and died even with aggressive treatment. This may suggest that neurological status and concomitant medical disease at presentation are important factors influencing the therapeutic outcome.

In conclusion, gas-containing brain abscess can result from *K. pneumoniae* infection or escape of air into the cranium through a fistulous communication due to basilar skull fracture or surgery involving the skull base. When encountered with gas-containing abscess in patients with an impaired host defense mechanism, *K. pneumoniae* infection should be suspected and further attention should be paid to discovering if other metastatic septic abscesses exist. For patients with a history of basilar skull fracture or surgery involving the skull base, craniotomy is indicated to excise the abscess and repair the potential fistulous communication through the cranium. Aspiration may be a reasonable alternative to treat deep-seated lesions, lesions in an eloquent area, patients with severe concomitant medical disease, or patients without a history of basilar skull fracture or surgery involving the skull base. Prompt diagnosis, appropriate antibiotic use, and meticulous surgical treatment are the only way to obtain a favorable outcome.

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